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ABSTRACT

Adaptive assistance in distributed learning environments (DLEs) provides new and exciting possibilities through the full exploitation of data captured from the interaction of the different actors with information processing, collaboration, and self-management tools. This paper presents a process to build adaptive assistance in a DLE. A DLE is rich enough to anchor a diversified user model, including the user's competency achievements, the user's affective reactions to the activities and resources, the user's collaboration patterns within a group and the user's metacognitive activity. Together with a model of the group and of the environment, these three models contribute to a diagnosis and a selective display of information intended for human or computerized assistance agents. (Contains 17 references.) (Author)

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Abstract. Adaptive assistance in distributed learning environments (DLE) provides new and exciting possibilities through the full exploitation of data captured from the interaction of the different actors with information processing, collaboration and self-management tools. We will present a process to build adaptive assistance in a DLE. A distributed learning environment is rich enough to anchor a diversified user model, including the user's competency achievements, his affective reactions to the activities and resources, his collaboration patterns within a group and his metacognitive activity. Together with a model of the group and of the environment, these three models contribute to a diagnosis and a selective display of information intended for human or computerized assistance agents. **Key words**. Adaptive Assistance. Student modeling. Distributed learning environments. Intelligent distance learning. Web-based training systems

1. Adaptive Assistance in a DLE

The now ubiquitous availability of multimedia telecommunication opens up a realm of new opportunities for learning in networked environments through a Distributed Learning Environment (DLE). Our DLE model (Paquette, 2001, Paquette,1997) emphasises the concept of process-based learning scenario coupled with information

Individualized tutoring	*Network-based Assistance*
Individualized, learner- computer tutor relationship	Collaboration, multi-actor, multi-agent relationships
Computerized tutor is the main if not the only learning material	Multiple resources integrated into the on-line environment; external information
Assistance from the tutoring module of an ITS	Multiple human and computer assistance agents
Fixed and limited set of instructional strategies	Flexible learning scenarios and strategies
Close guidance to the learner	Learner self management
Specific knowledge, precise goals	More generic, flexible, adaptive goals
Observation data is continuous and closely linked to the target knowledge and skills	Observation data is partial and loosely related to a set of target competencies

Table 1 – Individualized vs network-based assistance or tutoring

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processing, collaboration, self-management and assistance resources. Basically, the learner proceeds according to a scenario, a network of learning activities, using different kinds of resources to help her achieve the tasks and produce some type of outcome: a problem solution or new information that can be used in other activities. He/she interact with other actors such as trainers, content experts, designers and managers.

Adaptive assistance to these actors, based on knowledge of their activities and productions, is even more important than in the past because of the complexity and flexibility of network-based learning environments. But the problem is quite different than in individualised ITS research (Anderson, Corbett, Koedinger & Pelletier, 1995; Clancey, 1993; Wenger, 1987). It provides large areas of unexplored territories especially towards the full exploitation of the multiple data sources captured from the interaction of the different actors with the resources involved in a distributed learning event. Table 1 provides a brief comparison between individualized tutoring and network-based assistance.

2. Assistance in the Explor@ system

At delivery time, the learner and the other actors interact within a computerised learning environment. Figure 1 presents such an environment where the specialized content of a course is displayed in a browser (the host system) and the generic resources are distributed into five interaction spaces, self-management, information, production, collaboration and assistance, accessible in an Explor@ navigator, according to an actors' role and course specificity. The resources can be generic tools developed specifically for the Explor@ system, generic commercial tools or web resources (used in many courses) such as a technical FAQ, a virtual library, an agenda or a calendar.

2.1 Assistance in a Distributed Learning Environment

Whatever the agents, human or computer-based, the assistance must be « intelligent », that is, informed of the user, of the kind of tasks he is involved in, of the information he has consulted or produced, of the interactions and collaboration with others, and finally of his use of the assistance resources and self-management. In another words, the central question of ITS research, the user model, reappears in distributed learning systems, but in quite a different context [6]. We will give here priority to well informed assistance by human facilitators, without excluding direct intervention from computerized agents.

2. The learning environment model

Using instructional engineering methods and tools (Paquette, 2001, Merril, 1994) a designer can produce the specifications of the host learning environment. The user model will be built in relation to the model of host environment as opposed of the specific implementation of the "physical" system. The advantages of such an approach have been discussed in (Paquette, Pachet, Giroux, Girard, 1996; Paquette, Girard, 1996).

In the Explor@ system, we actually model the host environment into three kinds of hierarchical structures.

- The *instructional structure (IS)* groups the activities or operations that the learner can enact in the environment, from the program or course, down to the modules, the activities and finally the elementary steps where the learner consults, use or produces a resource (document, tool, service, etc.).
- The *knowledge and competency structure (KS)* decomposes a main knowledge object into related parts down to simple skills that apply to knowledge in the structure.

— The *resource structure (RS)* is composed of the list of resource spaces (information, production, collaboration, assistance, self-management) subdivided into individual resources.

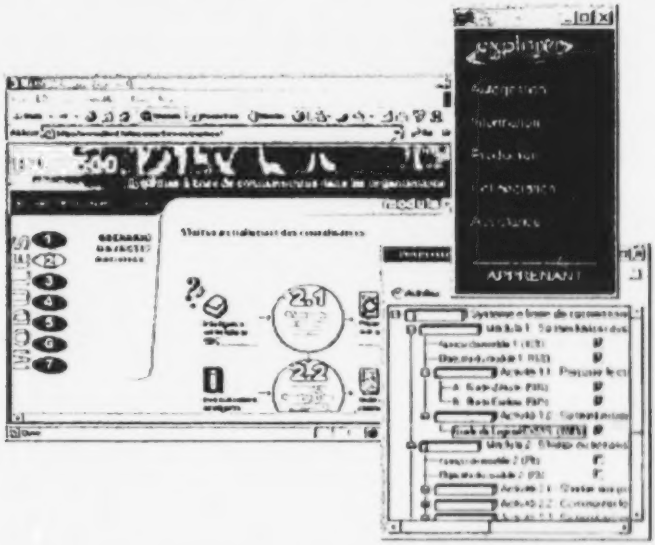

Figure 1 – A host web environment and an Explor@ resource navigator.

2.3 The "progress" part of the user model

To provide adaptive assistance to a learner, we need first to consider his position and progress into each structure of the learning environment model. The definition of adaptive assistance towards progress in the activities is actually done through an interface where the designer of the advisor first describes the IS and the KS, define simple templates to update the user model, and displays an advice or engages in a dialogue with the user (Lundgren-Cayrol, Paquette, Miara, Bergeron, Rivard, & Rosca, 2001). The advisor system also enables the designer to define tailor-made rules for the same purpose.
The learner model is updated essentially in three ways: by the designer's predefined templates or rules, by querying the user or by some action taken by the user can take to modify the model. The progress model is inspectable through a bar graph diagram (figure 1) that changes with the completion of the activities in the IS instructional tree structure.

3. Modeling users and groups

The user model described in section 2 is generic, that is applicable whatever the knowledge domain. But it is incomplete, limited to showing the learner her progress in the activities (in the IS) or in the knowledge and competency acquisition (in the KS). In this section, we will describe a process to build a more complete user model, that fully accounts for the knowledge and competency structure (KS), and also using data from the user's interaction with the collaboration and self-management resources.

3.1 The Modeling Process

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The main objective of the modeling process presented in figure 2, is to build and combine attributes enabling assistance adapted to the needs of each learner.

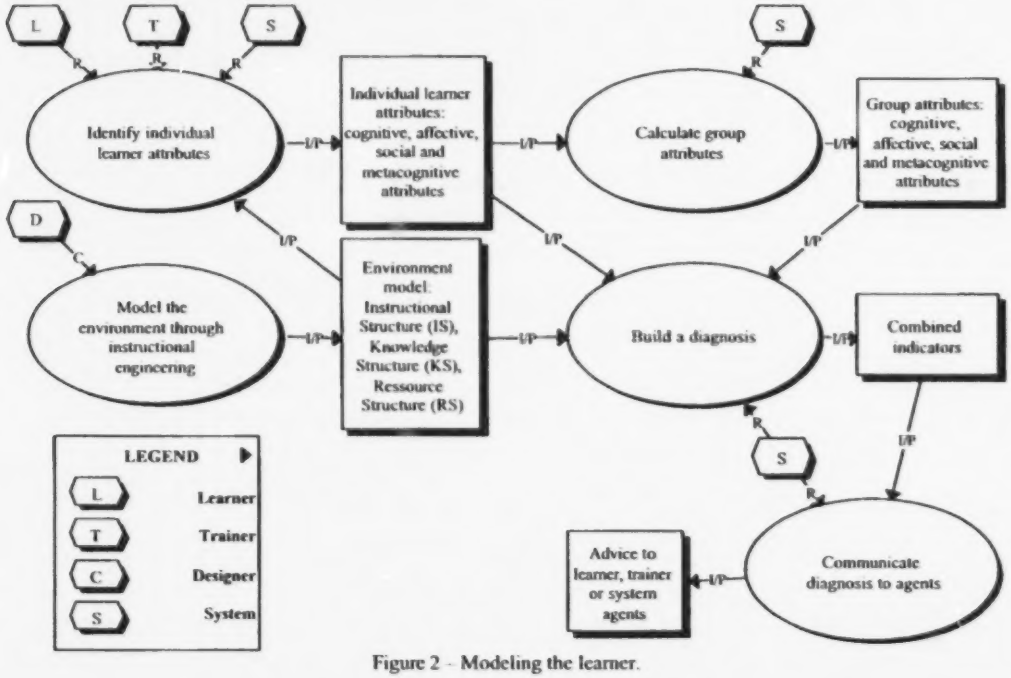

Figure 2 - Modeling the learner.

The learner (L), the trainer (T), the designer (D) and the assistance system (S) built by the designer participate to this display of the five sub-processes involved. The first process models the learning environment. It supplies information about the instructional structure, the cognitive structure and the resource structure, targeted towards the type of assistance that the designer intends to build. The second process tracks down the characteristics of the learner through her use of the environment. It embeds cognitive, affective, social and metacognitive attributes. The third process deduces, calculates and compiles group attributes from the individual learner's attributes. All this information is related and analyzed by the fourth process, the diagnostic one, opting to identify learning needs and learner's potential problems. Finally, the compiled attributes, needs and problems are communicated to an appropriate assistance generator, either for the learner, a trainer, a peer helper or a computer agent by the last process.

3.2 User model and the learning environment model

The modeling process draws a dynamic portrait of the user by tracking down a series of data based upon the interactions carried out in the learning environment. This portrait supplies a certain number of cognitive, affective, social and metacognitive attributes obtained by relating the learner's action with resources in the environment.

Cognitive attributes. The cognitive attributes derive from the knowledge and competency structures involved in the learning activities and productions achieved by the learner. We have developed a taxonomy of skills that helps define a scale of competency and performance levels corresponding to the acquisition of a certain knowledge unit (see [7]). The designer defines the entry level (DEC) and the target level (DTC) for each competency to be acquired in a learning activity. Then the learner is invited and encouraged to evaluate and compare, on a regular basis the state of her actual (LAC) and target (LTC) competency level. The trainer assesses the learner's productions or performances, yielding another value for the actual

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competency (TAC) of a learner. Depending on the relations between these values, it is possible to identify some learner's needs or problems. For example, if TAC < DEC, then the learner does not have the entry level competency stipulated by the designer and a prerequisite course is activated. The distance between TAC and DTC is important especially if a large time interval has elapsed since the beginning of the learner's activities within the course. For each activity in the instructional structure (IS), the associated competencies are evaluated and integrated in the learner's model.

Social attributes. The needed information is obtained by tracing the learner in her use of the collaboration resources in the learning environment, for example emails, forum, chat, videoconference, production showcase and so on. For each of these collaboration tools, some functions will have to be selected and the corresponding data captured. For example, how many messages does a learner send, by email or in a forum, to whom and on what subject? Previous work on forum analysis can contribute to this goal (Ricciardi-Rigault, Henri, 1994).

Affective attributes. The affective attributes are very important in a learner model but hard to track down because of the limited capabilities of today's computers. Emotional states are initialized through the use of an attitude pre-test. A special annotation tool is under construction and will be used to capture changes in attitude and emotions of the learner towards activities in the IS and resources in the RS. This annotation tool can be used anywhere in the learning environment and the learner can use it to enter small written messages, validated through a set of emotional values (Aubé, 2000) ranging from positive emotions (pride, gratefulness, joy, hope), to neutral, or negative emotions (fear, sadness, guilt, anger).

Metacognitive attributes. The Explor@ learning environments put a strong emphasis on self-management tools to help learner plan her activities, evaluate her progress, compare her results with other learners, and decide on a new course of action at a any point in time (Ruelland, 2000). Metacognitive attributes are discovered by the way the learner uses the self-management and assistance tools provided in the learning environment: the frequency of use, the consistency between the planned actions and the progress as well as the kind of modification the learner makes to her training plan.

3.3 Group model and the individual learner models

The model of a group contains group attributes on cognitive, social, affective and metacognitive dimensions. Individual scores of all members of the group participate in the process. In certain cases, the result shows average, median, minimum or maximum scores. In other cases, the distribution of learners in different categories is computed. Still in other cases, it builds the graph of all exchanged messages between learners and analyze it for clusters, number of links at a certain point, transitivity attributes and so on. In the affective evaluation of an activity or a resource, the group model shows how students distribute between emotions.

4. Combining attributes for diagnosis and assistance

We conclude this paper by giving a few examples of the combined use of the three models discussed (environment, user and group) to build a set of diagnostic attributes used to provide adaptive assistance to the learner. We will emphasize the possibility to give advice taking into account, cognitive, social, affective and metacognitive features of the models.

4.1 Diagnostic process

The diagnostic process goes beyond the descriptive models that capture the learner's individual attributes or the group attributes. It participates in the identification of learner's problems and diagnosis. Learning problems uncovered by educational research, particularly in the distributed learning field, feed this process. A diagnosis consists of a problem, its sources of difficulty and the attributes either essential or contributory,

describing the problem. During this process, the system watches the manifestations of these attributes in the learner model and establishes, in terms of percentage, the probability that a hypothetical problem is a true problem for a learner.

The problem. For example, persistence has been the subject of numerous researches in the field of distributed and distance learning. The risk of dropout is a problem highly relevant justifying its presence among hypothetical problems.

The attributes. The diagnostic attributes are collected from the attributes available in the three descriptive models of the environment, the learner and the group. They are also obtained through comparisons between these attributes. Table 2 presents a list of examples of such attributes, together with the DLE resources used by the learner, and the model into which they can be found.

Diagnosed attributes	*From resource*	*In model*
1. Distance between the learner actual competency and the entry level defined by the designer	Self diagnosis tool	Learner model, Environment model
2. Values of learner's actual competencies lower than those of the group	Self diagnosis tool	Learner model, Group model
3. Distance between values of learner's actual competencies and those estimated by the trainer.	Self diagnosis tool, Tutor assessment tool	Learner model
4. Delay in the delivery of learner's productions	Progression tool, work plan tool	Learner model
5. Delay in achievement of the activities according to the work plan	Work plan tool	Learner model
6. Slower progress in the activities compared to the group	Work plan tool	Learner model Group model
7. Negative feelings	Annotation tool	Learner model
8. Absence or important decrease of the use of the resources of information, collaboration, assistance and of metacognition.	Progression tool	Learner model
9. High risk of failure (90%)	Inference from the system	Learner model

Table 2 – Example of diagnostic attributes

Some of these data are considered essential while others have a contributory character in that they participate in the description of the problem without being essential to the confirmation of the problem.

The sources of difficulties. The sources of difficulties associated to a problem are going to steer the attention of the trainer or learner on the causes of that problem. They derive from an analysis of the attributes and from their relationship with the cognitive, emotional, social or metacognitive domains. Thus, the sources of difficulty of the learner who demonstrates the attributes 1,2 and 7 of the above list would be of cognitive and emotional nature.

The percentage of credibility. This value is expressed on a continuum for example, persistence / dropout in the above mentioned case and is calculated by a set of rules according to the presence of the essential and contributory attributes in the descriptive three models. The percentage of credibility has two functions. It gives an appreciation of the probability that the hypothesis is really a problem for the learner. It could also be used to establish a priority order among possible problems. This will allow steering the attention of the assistance agent towards some priorities.

All attributes are obtained from the descriptive learner model. The attributes 2, 6 result also from the group model and the attributes 1, 4, 5, from the model of the learning environment. So the three models contribute to supply a critical vision on the learner.

The method described above is an inductive approach to diagnosis (Self, 1990) linking diagnostic attributes to a problem. Other learner problems can be added to the list using an editor to be added to the DLE to allow the trainer to add a diagnosis based on the inspection of the descriptive models. The trainer can either select a problem within a list of hypotheses supplied by the designer or formulate a new problem based on his inspection of the attributes of the descriptive models. He then establishes a concrete relation between the proposed diagnosis and the descriptive model attributes to communicate his perception of the learner

problems. This approach informs the designer of learner difficulties not yet listed in the learning environment thus participating to its improvement.

4.2 Communicating diagnostic results

Learners, trainers and designers have different roles and needs regarding the information contained in the models and the diagnostic attributes. It is then advisable to select and organize the information in order to respond to the special needs of each actor.

For example, a learner who wishes to compare his results with those of the group, consults a graphs displaying the group results if the DLE integrates this possibility. In other occasions, a learner has the chance to consult his results and attitudes related to instructional structure before choosing in a range of activities.

The trainer, on his part, receives an orderly list of possible learner's problems. The agent consults and evaluates the appropriateness as well as the type of intervention to establish. The trainer can consult the individual learner's models and the group model before adopting a strategy of assistance. He can also ask to be informed when certain diagnostic attributes have reached a threshold of critical credibility. In the above example, the trainer should be informed about the position of the learner on the persistency/dropout continuum. In accordance with Self's (Self, 1990), all of the attributes need not to be identified. A trainer, who suspects a learner problem, identifies the missing attributes in the learner model and establishes his strategy to obtain the missing information.

The designer as well, has specific needs. This actor will be interested mostly by the group model, the most significant of the three, to improve the learning environment. Inspecting the attributes and problems of the group will direct his attention towards weakness in the design. Learning that a whole group feels anger regarding an activity or experiences difficulty in meeting a target competency will probably help him to implement certain modifications in the cognitive, pedagogical or resource structures.

Conclusion

Proposing summaries tuned to the role of the actor who requested it, approaches the question of learner assistance in a broader way than direct assistance from the system. It is inspired by the "human-in-the loop" approach (Kumar, V., 2001), an approach that was built, right from the start, into the architecture of the Explor@ system and the DLE model we have referred to in this paper. The multi-agent view is focused on a continuous and recursive collaboration between human agents, the actors, and computerized agent, including those giving or helping actors to provide adaptive assistance to the learner.

The approach to adaptive assistance we have proposed here is wide and ambitious. Each dimension of the learner model and the group model has witnessed much research in the past, especially for the cognitive dimension and, more recently, for the social dimension. What we propose here is not to go in depth on any dimension but instead, to use previous research results, to add new elements for the affective and metacogntive models, and to integrate them in combination to detect important learning problems.

Even though we have focused on assistance to the learner, most of what we have described can be adapted to other actors in the environment. Some of our colleagues are presently working on similar schemes to provide assistance to designers.

Finally, we hope to progress in this research in a way to provide guidelines and tools to designers to enable then to integrate new resources in Explor@ DLEs, not only to contribute to learning scenarios, but also to provide ground for adaptive assistance to those scenarios.

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